Plasma processing for fabrication and modification of PMMA microfluidics

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The fabrication of microfluidic devices with features of 10-1000 um size are of great importance in many fields of analytical science, where a small quantity of sample is available, enhanced resolution and sensitivity in separation is needed and increased functional integration is desired (medical, chemical and biochemical analysis, microchemistry etc) [1]. Even though the first microfluidic devices were fabricated on silicon and glass, the need for easy fabrication, low cost and disposability has recently shifted the attention on polymeric materials.

Microfabrication of polymers can be attained through many techniques such as hot-embossing, micro-casting etc. The implementation of these methods entails the need for a mold fabrication, using standard microelectronic processes. Recently, deep plasma etching of polymers [2],[3] has been proposed for the fabrication of polymeric microfluidic channels, thus introducing, a mold-free method. The implementation of plasma treatment presents some unique merits in that (i) plasma etching is an inherently mass production technique, (ii) the polymer is treated while being in its solid state, (iii) channel formation is performed in rather low temperatures (cold-plasma), and (iv) within the same plasma reactor several surface physicochemical and mechanical properties (wettability, hardness etc) may be modified, towards the requirements of the specific application.

In this work we employ plasma processing to fabricate and modify PMMA-based microfluidics. Photosensitive polydimethyl-silicone (PDMS) is used to pattern the polymethyl methacrylate (PMMA) during oxygen plasma environment, avoiding thus the use of hard metallic masks [3],[4]. Etch rate was optimized (see Fig. 1) to minimize the process time to create microtrenches of ~ 30 um depth of various widths (see Fig. 2) 30 min (average ER ~ 1.5 um/min). Their surface characteristics were controlled from fully hydrophilic (contact angle, CA < 10^o) to super-hydrophobic (CA ~ 150^o). Electrosmotic flow (EOF) measurements of the phosphate buffer were carried out, and found to be greatly influenced from the time after the fabrication, revealing the existence of ageing phenomena. While after the fabrication EOF mobility is rather high (higher than the electrophoretic mobility of a dye like Eosin B) when the microfluidic ages the EOF is lower than the electrophoretic mobility of Eosin B; in this state a negatively charged substance (Eosin) moves towards the anode, with decreased velocity due to the EOF flow (Fig. 3).

Acknowledgments. Funding was provided by (a) "HERAKLEITOS" project No. 68/640, (b) NCSR "D" internal fellowship program and (c) NanoPlasma project, IST-NMP-3, Contract No. 016424.

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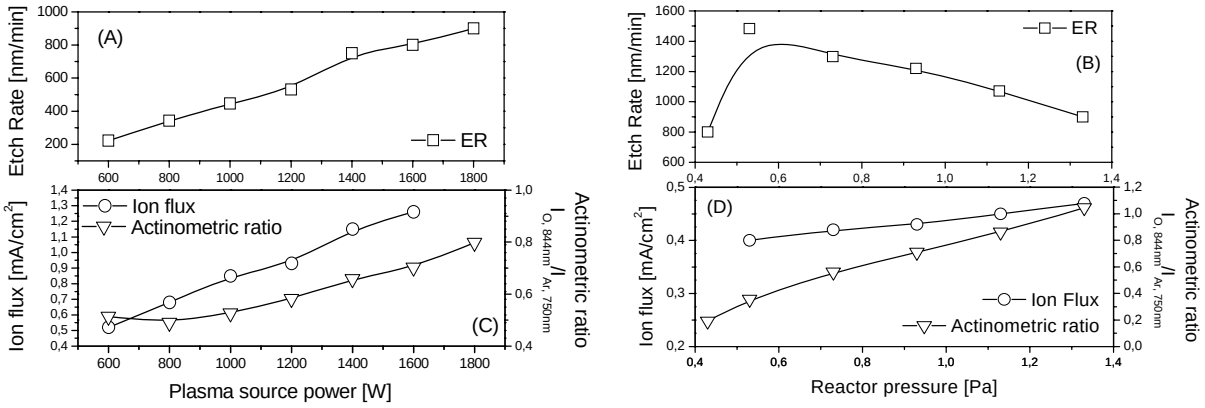

Fig. 1 (A) O_2-plasma etch rate measurements of PMMA vs. plasma source power [Electrode temperature: 15°C, Bias Voltage: -100V, O_2 flow: 100sccm, reactor pressure: 1.33Pa]. (B) O_2-plasma etch rate measurements of PMMA vs. reactor pressure [Electrode temperature: 15°C, Bias Voltage: -100V, O_2 flow: 100sccm, plasma source power: 1800W]. (C) Actinometric ratio $I_{O(844nm)}/I_{Ar(750nm)}$ and ion flux measurements of the oxygen-ICP vs. plasma source power and (D) vs. reactor pressure. The actinometric ratio in (D) has been appropriately treated to include the pressure dependence. In all cases lines are only to guide the eye.

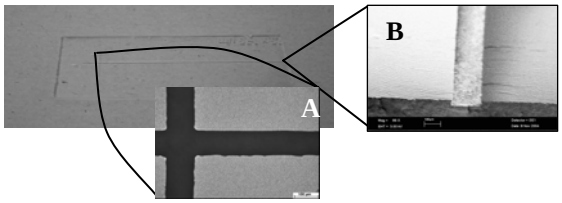

Fig. 2 The microfluidic channel before the sealing. The transparency of PMMA remains intact. (A) Detail of the cross by optical microscopy and (B) cross section of the trench by SEM.

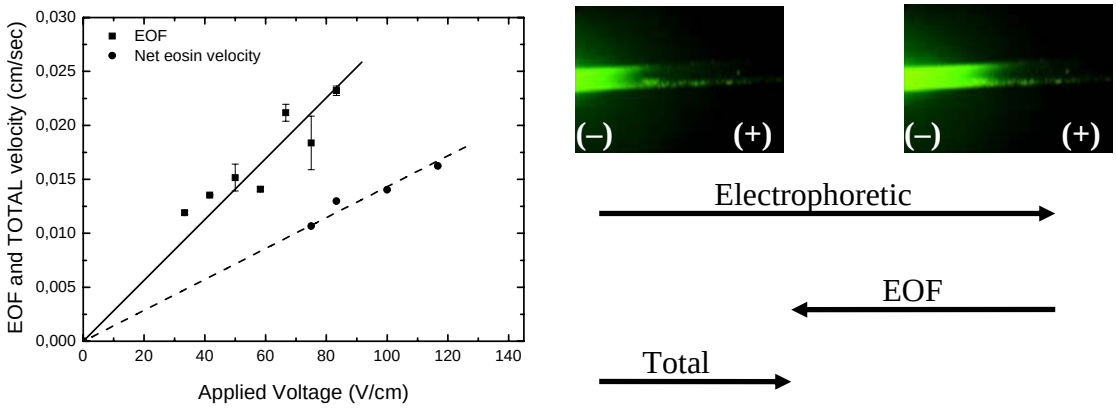

Fig. 3 (Left) EOF and net Eosin velocities against applied voltage (Right) Snapshot from the fluorescence microscope monitoring the negatively charged Eosin transport for aged microfluidic. EOF mobility is lower than the electrophoretic, causing the Eosin to move towards the anode.